BAREILLY INTERNATIONAL UNIVERSITY, BAREILLY

Computed Tomography Evaluations of Morphometric and Anatomical variations of Paranasal Sinus region

By

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A Protocol of Thesis to be submitted to the Bareilly International University, Bareilly for the partial fulfillment of the requirements for the award of the degree of

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in

Department of Anatomy

(BATCH 2018 – 2021)

under

FACULTY OF MEDICINE

Faculty of Medicine

(Affiliated to Bareilly International University, Bareilly)

DECLARATION BY THE CANDIDATE

I hereby declare that this thesis protocol entitled **"Computed Tomography Evaluations of Morphometric and Anatomical variations of Paranasal Sinus region"** will be a bonafide and genuine research work carried out by me under the supervision of***Prof. (Dr) Rakesh Gupta***for partial fulfilment of the regulations for the Award of the degree of **Doctor of Philosophy**in **Department of Anatomy**.

Date: **Signature of the Candidate**

(Sarangdharkumar)

Certificate by the Supervisor/ Co-Supervisor

Faculty of Medicine

(Affiliated to Bareilly International University, Bareilly)

This is to certify that the facilities for the research workentitled **"Evaluations of Morphometric and Anatomical variations of Paranasal Sinus region"**allotted to**Sarangdhar kumar** under my/our direct supervision and guidance do exist in the **Department of Anatomy**, Faculty of Medical Sciences.

I/we will ensure the authenticity of the thesis protocol topic and research methodology which conforms to the standards of Bareilly International University.

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Index

Topic	Page No.
Introduction	1-5
Brief review of literature	6-7
Aim & Objectives	7
Material & Methods	8-9
Bibliography (Vancouver system)	10-11
Appendix (Proforma/Data sheet, Consent form, etc.)	12-14

THESIS PROTOCOL OUTLINE

Cover Page	
Biodata of the Candidate	
Declaration by the Candidate	
Certificate from Head of the Dept.	
Certificate from Supervisor & Co-Supervisor	
Index	
Introduction	Page -
Brief review of literature	Page -
Aim & Objectives	Page -
Material & Methods	Page -
References (Vancouver system)	Page -
Appendix (Proforma/Data sheet, Consent form, etc.)	Page -

Introduction

Study of morphometric and anatomic variations of the paranasal air sinuses is important in patients who are undergoing radiology scan evaluation for various rhinologic reasons. Knowledge of the anatomic variations does reduce the surgical complication rates during functional endoscopic sinus surgery (FESS), helps explain recurrence of disease and allows one to change the operative technique. The ethmoid air sinuses play a crucial role in FESS. The posterior ethmoids and the sphenoid sinuses can be accessed via the anterior ethmoid cells. Anterior ethmoidectomy helps improve frontal air sinus drainage hence minimizing the need for opening the frontal sinus during surgery. The anatomic variations of paranasal sinus make the approach to FESS much more complex.[1]Some anatomic variants are probably not responsible for development of chronic rhinosinusitis, but knowledge of their presence is paramount.

Variations in the pneumatization of ethmoid sinuses may disturb sinus ventilation.[2,3] These can be the etiological factor for sinusitis and spread of infection to adjacent structures. During FESS, straying beyond the surgical field may lead to serious complications such as cerebrospinal fluid leak, meningitis, or blindness, so a detailed knowledge of the possible anatomical variations is essential.

Computer Tomography scan is a mandatory radiological investigation for patients undergoing FESS. CT scan helps identify these anatomic variations. Many centres use the three-millimetre cuts for all views – coronal, sagittal and axial to assess the different anatomical structures of the lateral nasal wall and the paranasal sinuses. The coronal views are best for the sphenoid and the ethmoid cell variants such as the onodi or sphenoethmoidal cell.[4]The development and refinement of CT scans has allowed extensive assessment of patients' paranasal sinuses thus providing a guide map for FESS surgeons to operate.[5]

Anatomy: Understanding the embryology and gross anatomy of the paranasal sinuses is of paramount importance in the surgical aspect due to its close proximity to vital structures such as the orbit and optic nerve.

Embryology:– The frontal, maxillary and ethmoid sinuses arise from evaginations of the lateral nasal wall, whereas the sphenoid sinuses arise from a posterior evagination of the nasal capsule. Embryological development of ethmoid sinus begins during the fifth month of intrauterine life as numerous evaginations from the foetal nasal chamber into the anlage of the ethmoid bone. At first this evaginations are mere slits, but they quickly grow into a tubular form before assuming a round or globular shape at term. The expansion of each air cell with rapid growth of the cells is at the expense of the ethmoid bone. The haphazard growth of cells makes each person's ethmoid labyrinth different from the next. The expansion of these cells continues until late puberty or until the wall of the sinus strikes a layer of compact bone or another sinus. By adulthood, the ethmoid block averages 3.3 by 2.7 by 1.4 cm in size, with the longest dimension being the anteroposterior. The ethmoids complete pneumatization by the age of twelve years.

Frontal sinuses are either absent or insignificant at birth, but gradually increase in size and reach maximum dimension at around age twenty years.[6] Further pneumatization due to atrophic changes may occur in old age.[7] Structural changes can only be caused by altercation due to tumours, fractures or severe infections.[8] The two develop independently hence often asymmetry. Maxillary sinus development begins at tenth week gestation as some mucosal

invagination of primitive ethmoid infundibulum. Shaping of maxillary sinus starts by fusion of multiple invaginations into a single cavity from week eleven. Growth is progressive in all dimensions more so anteroposteriorly, similar to the cranial elongation.[9] It undergoes two periods of rapid growth, between birth and age of three years, also between ages seven and eighteen years. A poorly developed infundibular passage is associated with hypoplasia.[10] Sphenoid sinus develops from evagination of sphenoethmoid recess at birth. Pneumatization begins age three and reaches sellar by age seven and proceeds rapidly after. Development continues until age twelve to fifteen years.

Gross Anatomy:– The ethmoid bone is a light, papyraceous, osseous structure attached to each edge of the cribriform plate as a block of ethmoid sinuses. Each block is made of a group of three to fifteen air cells. The ethmoidal cell block or labyrinth is pyramidal in shape, being wider posteriorly (where it abuts the sphenoid bone) than anteriorly (where it contacts the lacrimal bone). The ostia of the ethmoidal sinuses are the smallest found in any of the paranasal sinuses, measuring one to two millimetres in diameter. To understand the anatomic relations of the ethmoid labyrinth its best to consider it as a box. The roof of the box is the top wall or roof of the ethmoidal air cell box and is termed the fovea ethmoidalis. The fovea is not a flat plate of bone but undulating, because the domes of the topmost ethmoidal cells bulge into it and mold it into such a contour. The anterior part of the fovea lies more superior to the posterior part, since the anterior cranial fossa descends approximately fifteen degrees from a horizontal plane as it passes posteriorly. The lateral wall of the box is the lamina papyracea. It is a flat, smooth, rectangular plate of bone articulating with the frontal bone superiorly, the lacrimal bone anteriorly, the maxilla inferiorly and the lesser wing of the sphenoid bone posteriorly.

Along the frontoethmoidal articulation lie two foramina, the anterior and posterior ethmoidal foramina. Through these pass branches of the ophthalmic artery and trigeminal nerve to supply blood and sensation to the mucosa of the ethmoidal air cells.

The anterior side of the ethmoidal box abuts the lacrimal bone, the smallest of the facial bones. The importance of lacrimal bone is that it is frequently pneumatized with the group of anterior ethmoidal cells termed aggernasi. The posterior part of the ethmoidal box is formed by the back walls of the posterior ethmoidal cells. Because a large ethmoidal cell often abuts the sphenoidal sinus, these cells frequently share a common osseous wall. The inferior and medial walls of the ethmoidal box must be considered together, for they comprise almost a single slightly convex curved plane bowing into the nasal chamber. Thus, the ethmoidal sinuses do not lie directly atop the maxilla but touch the latter only at the upper medial part of the maxillary sinus.

Projecting into the nasal chamber from the medial wall of the ethmoidal block are the turbinates. The support of these structures is a partition of bone – the basal lamella – that continues from the base of the turbinate and traverses laterally through the mass of ethmoidal cells to attach to the medial side of the lamina papyracea. The inferior, middle and superior turbinate lamellae internally divide the intramural ethmoidal cells into anterior, posterior and postreme groups. The lamella in each case is not a straight divide because the developing air cells push and distort what was its original linear position in the foetal ethmoid bone. In general, the cells of the anterior ethmoidal group are more numerous (two to eight) but smaller, whereas those of the posterior group are larger but fewer in numbers (one to seven).

The sphenoid sinus is located in the sphenoid bone and may differ in size and shape depending with individuals. One or more vertical septa divide the sinus and the septa are rarely inmidline.[11]The degree of pneumatization of the sphenoid sinus may vary considerably. The sphenoid sinus can be described as conchal, presellar and sellar.

Radiological anatomy:– CT scan is the investigation of choice for paranasal sinuses. Modern multi slice CT scanner allow thin axial plane slices to be obtained, from which reconstruction to sagittal and coronal planes can be made. The coronal plane best displays the osteomeatal complex. The axial plane helps identify the basal lamella of middle turbinate which is the dividing point of anterior and posterior ethmoid sinuses.[4]

Ethmoid air sinuses are the most developed paranasal sinus at birth but are not evident on X-ray until the age of 1 year. Anatomical boundaries of anterior ethmoid cells are: anteriorly, the ethmoid infundibulum; posteriorly, the basal lamella; laterally, the lamina papyracea; superiorly, the skull base. Anatomical boundaries of posterior ethmoid cells are: anteriorly, the basal lamella; posteriorly, the anterior sphenoid wall; medially, the superior turbinate; laterally, the lamina papyracea; superiorly, the skull base.4

Aggernasi is the most anterior ethmoidal air cells. It forms the anterior inferior border of frontal recess. Its degree of pneumatization has significant effect on frontal sinus drainage and surgical access. Frontal recess may be displaced medially and posteriorly, depending on the size of aggernasi cell. Onodi cell is assessed by comparing both coronal and sagittal cuts carefully. They pneumatize superolateral to the sphenoid sinus: hence surgical clearance should be in the inferomedial direction, due to optic nerve and internal carotid relations.

Sphenoid sinus' most reliable landmark is the ostium which lies approx 1cm superior to the posterior inferior end of superior turbinate and approx 1.5cm superior to the choana. CT scan evaluation focuses on pneumatization and the relation to both internal carotid artery and optic nerve. The boundaries of the frontal sinus tract/ recess are: anteriorly, the aggernasi cell; posteriorly, the ethmoid bulla and skull base; laterally, the lamina papyracea and medially, the middle turbinate.

Anatomic Variants: Concha bullosa: It is pneumatization of the concha. The middle concha is the most commonly involved. Bolger et al classified concha bullosa pneumatization as per the location into lamellar, bulbous and extensive. The extensive type is the combination of both the lamellar and bulbous type. Pneumatization of the middle concha is the extension of normal pneumatization of the ethmoid cells.[12]This is usually by the anterior ethmoid cells but the posterior ethmoid cells have also been documented or by both groups. Concha bullosa is implicated in the pathogenesis of rhinosinusitis because of its tendency to narrow the middle meatus and the infundibulum. Some studies have found the prevalence of concha bullosa to be the same in patients with and without sinus disease symptoms.[13]

- Superior Concha bullosa: Pneumatisation of superior turbinate is extremely rare condition.
- Inferior concha bullosa: Pneumatization of the inferior turbinate as well is very rare.

Keros classification: the length of the lateral lamella of the cribriform plate, defining the type of olfactory fossa. In most of the cases, the cribriform plate is symmetrical; however, an asymmetric skull base is an anatomic variant.

- Type I: cribriform plate 1-3 mm below fovea ethmoidalis.
- Type II: 4-7 mm below fovea ethmoidalis

- Type III: 8-16 mm below fovea ethmoidalis

Nasal septal deviation: Asymmetric nasal septum position which can put force on nasal turbinates.

Haller cells:– Pneumatization of ethmoid cells extends into anterior roof of maxillary sinus, along the floor of the orbit. They are an etiological factor for sinusitis since they vary in size and when large can narrow the ostium of the maxillary sinus or the ethmoid infundibulum. The presence of an infraorbital cell may increase the risk of injury to the orbit during FESS, an unrecognized cell masking the position of the orbital wall.[14] Bolger et al defined a haller cell as any cell located beneath ethmoid bulla, lamina papyracea or orbital floor.

Aggernasi cells:– Most anterior ethmoid air cell located below the frontal sinus and are intimately related to the frontonasal recess, reaching the lacrimal fossa inferolaterally. They are anterosuperior to the hiatus semilunaris. The aggernasi cell may form a significant part of the anterior wall of the frontal recess and impinge upon the frontal sinus drainage tract. Recognition of this relationship is crucial in management of chronic frontal sinusitis.[15]

Onodi cells: – posterior ethmoid cells that extend posterior, lateral and always superior to sphenoid sinus, lying medial to the optic nerve. First described by Adolf Onodi in 1903. Extensive pneumatization can expose the circumference of optic nerve, which is surrounded by air spaces, mainly the inferior half.[16]Onodi cells are also known as sphenoethmoid cells and are important to the surgeon in FESS. When present, both optic nerve and carotid artery may be exposed in the posterior ethmoid cell.[17]The best orientation is on axial cuts where the course of optic nerve can be followed as a relation.[18, 19]

Uncinate bulla:–Pneumatization of the uncinate process and is a rare entity. Uncinate process projects from the ethmoid bone to the ethmoid process of the inferior nasal concha. Pneumatization can result in narrowing of infundibulum and sinus drainage occlusion.[20]

Maxillary sinus hypoplasia: – Uncommon condition that is misdiagnosed as chronic sinusitis.[19]In its severe form, it impedes mucociliary clearance and is liable to retention of mucus. Failure to recognize maxillary sinus hypoplasia intraoperation can lead to injury to the medial orbital wall.[20]Finding the maxillary sinus ostium may be difficult.[21] Classification of maxillary sinus hypoplasia:

- Type 1. Mild sinus hypoplasia: Normally developed uncinate process.Well-developed infundibular passage.Varying degree of mucosal thickening of affected sinus.

- Type 2. Significant sinus hypoplasia: Hypoplastic or absent uncinateprocess.Ill-defined or absent infundibular passage.Total opacification of affected sinus.

- Type 3. Profound sinus hypoplasia: Sinus represented by shallow cleft in the lateral nasal wall of the nose. Absent uncinate process.

Sphenoid sinus hypoplasia:– Defined as an oval-shaped sinus with pneumatization limited to the presphenoid that is anterior to the vertical plane of the tuberculum sellar. It is an uncommon condition. Few cases of agenesis have been reported.[22]Mainly seen in patients with craniofacial anomalies and skeletal diseases.[23]

Sphenoid sinus pneumatization:– It can be divided intoconchal, presellar or postsellar. Conchal: the area below the sellar is a solid block of bone without pneumatization. Presellar: the sphenoid is pneumatized to the level of the frontal plane of the sellar and not beyond. Sellar: the most common type, where pneumatization extends into the body of the sphenoid beyond the floor of sellar and reaches clivus.

Frontal sinus hypoplasia:– It is uncommon to find one dominant, one hypoplastic or both hypoplastic frontal sinus. Rarely both aplastic frontal sinuses.[24]

Brief Review of Literature

Paranasal sinus anatomy is variable from individual to individual and so is the incidence of the anatomical variations. Different studies around the globe demonstrate different percentages for the anatomic variations. As for CT scan, it being the imaging modality of choice, most authors use three millimeter coronal plane cuts as it gives similarity with surgical orientation. Axial plane cuts are used for a clearer, exact diagnosis when coronal plane is not clear.

Stammberger and Hawke have shown that CT scan of PNS provides an anatomic road map to identify presence of abnormalities, the location and severity of disease and exact location of obstruction.[19] CT scan in a coronal plane is more informative than on an axial plane as indicated by Perez P et al. This shows anatomical structures progressively as a surgeon's visualization and the relationships of sinus cavities and adjacent structures. Axial cuts are also imperative, since they give anatomical relations of the paranasal sinuses.[25] Perez had a sample size of one hundred patients of whom nearly all had aggernasi cells while 73% had concha bullosa and 3% had haller cells.

Removal of disease in the osteomeatal complex region is the basic principle of FESS, which is best appreciated on CT scan as documented by Dua et al[26] whose sample size was fifty patients. Fourty percent had aggernasi cell while both haller cells and concha bullosa had 16% each. Mamatha H did re-emphasize the concept that osteomeatal complex is the key factor in the causation of chronic sinusitis.This study also gave justification as to why the coronal plane is preferred, since it displays the osteomeatal complex best.[27]Mamatha had a sample size of forty patients and nearly half of them had aggernasi cells while 17.5% had haller cells and 15% had concha bullosa. In a study by Hatipoglu, he looks at the statistical relationship between concha bullosa type and osteomeatal disease, hence concluded that pneumatization of the inferior part of the middle concha plays a major role in osteomeatal disease development.[28]

A comparison of anatomic variants in patients with sinus disease and patients without was made by Kayalioglu. Clearly anatomical variants were common in patients with sinus disease.[29] His sample size was ninety sinus patients and eighty-two non-sinus patients. Concha bullosa which was close was seen[28]. 8% in sinus patients and 26.8% in non-sinus patients. Basic who did a CT scan study to determine frequency of anatomic variations in mainly ethmoid pneumatization and did indicate it is imperative to adopt standardized classification and definition of paranasal sinus variations. This would avoid discrepancies amongst various authors.[30]A study by Arslan H et al had a large sample size of two hundred patients and looked into anatomical variants of the paranasal sinus on two millimeter CT scan cuts where he found that 30% had concha bullosa while onodi cells at 12% and haller cells were 6%.[14]

A comparison of prevalence of anatomic variation on CT scan and clinical findings was made by Lerdlum, who observed that anatomic variation can compromise mucociliary drainage. However, only large aggernasi had significant correlation to inflammatory sinus disease.[31] A study on aggernasi cell, the key to understanding anatomy of the frontal recess was done by Wormald The anatomy and variations in the area are poorly understood by FESS surgeons. Reconstructed CT scan cuts of PNS, mainly coronal and sagittal aid in identification of each cell and assist the surgeon to formulate a clear, precise surgical plan.[32]

Study Justification

This study offers local statistics on paranasal sinus anatomy and its variants. It acts as a baseline research for anyone who wishes to carry further studies on particular paranasal sinuses. This data will help the otorhinolaryngologist to build a complication free learning curve, assist in local training and also emphasize on the need for radiological evaluation. This study helps in standardization of the cuts size and view to request for in terms of paranasal sinus CT scans. Clear information on trends of variation among the local population can be obtained in the
study. Paranasal air sinuses are important in FESS and knowledge of its anatomical variants helps a surgeon in his/ her orientation during FESS.

Aims and Objectives

To determine the incidence of paranasal air sinus morphometric and anatomical variations in patients undergoing CT scan evaluation at Rohilkhand Medical College and Hospital, Bareilly.

Specific Objectives

1. To determine demographic characteristics of patients requiring paranasal CT scanning at Rohilkhand Medical College and Hospital.
2. To determine radiologic variants of paranasal air sinuses among patients undergoing CT scan evaluation at Rohilkhand Medical college and Hospital.
3. To study the incidence of morphometric and anatomical variations of osteomeatal complex common in chronic sinusitis patients.
4. To study the anatomical variation commonly associated with each paranasal sinus inflammation.
5. To study the importance of pre-operative computed tomography evaluation of the paranasal sinus and osteomeatal complex variation in chronic sinusitis patients.

Materials and Methods

Study design: Prospective cross-sectional study.

Sample size: We want to estimate the proportion of population with anatomic variations of paranasal sinuses in patients undergoing CT scan evaluation.

1. 300 patients will be studied during the period of July, 2019 to June, 2021 in our institute.
2. The age of the patients selected ranged from 17 year to 55 year of which 163 were male and 137 were female patients.
3. After selecting the patients, they were subject to endoscopic nasal evaluation.
4. All these patients will be then evaluated with CT scan para nasal sinus.

Patients selection criteria:

1. Adult patients > 17 year with complaints suggestive of chronic sinusitis for a period more than 12 weeks including those with acute exacerbation of chronic sinusitis.
2. Patients who fulfil the criteria for chronic sinusitis clinically.
3. Persistent chronic sinusitis despite medical therapy (requiring surgical management)

Exclusion criteria:

1. Patients with acute sinusitis
2. Patient with mass or polyp obstructing the nasal cavity.
3. Patients who were previously operated.
4. Patient with facial anomalies

Patients preparation before CT Scan:

- A course of antibiotics, nasal decongesants and antihistaminics given for a period of 4 weeks
- Nasal decongesants (xylometazoline) – 15 minutes prior to CT scan.
- Patient asked to blow the nose forcefully just prior to CT scan.

CT scan was performed in a Bright Speed Elite-16 machine of Wipro GG health care private limited company CT in Department of Radiology, Rohilkhand Medical college and Hospital.

Direct coronal sections imaging will be done in all patients. Limited axial scans parallel to the orbitomeatal line with the patients in supine position, will be carried out whenever required. All films are taken without contrast. No intravenous contrast will be used.

Morphometric evaluations will be carried out by using areas of each tomographic slice by carefully tracing the area measurement functions of CT scanner. The volume of CT in each section will be calculated by multiplying area with the slice thickness. By summing all volumes of every slice based on the Cavalieri principal for volume calculations, the total volume of areas will be expressed in cubic centimetres as mean of standard deviations.

Statistical analysis: SPSS for Windows 11.0 will be used for the statistical assessment. Analytic assessment will be carried out by the Students t-test and Kruskal-Wallis test and P value less than 0.05 will be taken as statistically significant.

Implications of the study:

Our present prospective study of anatomical variation of paranasal sinuses with the proper pre-operative evaluation of morphometry, we can reduce inadvertent complications during surgery and also ensure the complete clearance of the disease.

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PARTICIPANTS INFORMED CONSENT FORM

Evaluations of Morphometric and Anatomical variations of Paranasal Sinus region

Protocol/Study Number :

Participant Identification Number :

Name of Principle Investigator :

Contact No. of Principle Investigator :

The content of the information sheet dated ..... (Version) ..... that was provided have been read carefully by me / explained to me, in a language that I comprehend, and I have fully understood the content. I confirm that I have had the opportunity to ask questions regarding this study.

The nature and purpose of the study and risks related to the study and its potential risks/benefits and expected duration of the study, and other relevant details of the study have been explained to me in detail. I understood that my participation is voluntary and that I am free to withdraw at any time, without giving any reason, without my legal right being affected.

I understand that the information collected about me from my participation in this study may be looked at by responsible authority and my identity will be kept confidential. I give permission for these individuals to have access to my records.

I agree to take part in the above study.

.....

Date:.....

(Signature/left thumb impression) Place:.....

Name of the participant .....

Address of participant .....

.....

This is to certify that above consent has been obtained in my presence.

Signature of the principle investigator

1) Witnes-1

Name

Address

2) Witness-2

Name

Address

THESIS PROFORMA

Evaluations of Morphometric and Anatomical variations of Paranasal Sinus region

Personal details:

1. Clinic Number:
2. Date (DD/MM/YY):
3. Enrolment Number:
4. Name:
5. Gender (0-Female, 1-Male):
6. Age (years):
7. Marital Status (1-single, 2-married, 3-widow, 4-divorced):
8. Address:
9. Phone Number: (Secondary Contact)

History:

1. Smoking:

- Smoker (0-No, 1-Yes):
- If yes, pack per years:

2. Significant Alcohol Consumption:

- (0-No, 1-Yes) ☐

3. History of Type 2 diabetes: ☐ (0-N0, 1-Yes)

4. History of Hypertension: ☐ (0-N0, 1-Yes)

5. History of Dyslipidemia: ☐ (0-N0, 1-Yes)

6. History of Hypothyroidism: ☐ (0-N0, 1-Yes)

7. Habitual Snoring: ☐ (0-N0, 1-Yes)

Anthropometric Details:

1. Height (cm): ☐
2. Weight (kg): ☐
3. BMI (kg/m^2): ☐
4. Neck Length: ☐
5. Neck circumference (cm): ☐
6. Waist circumference (cm): ☐
8. Hip circumference (cm): ☐
9. Wait/hip ratio (WHR): ☐
10. Systolic blood pressure (mm/Hg): ☐
11. Diastolic blood pressure (mm/Hg) ☐